The content of this note is based on information received from manufacturers in the electrical and electronics industries or their representatives and does not imply practical experience by Elektor Electronics or its consultants.

precision current gauges

with low-loss sense element and PWM output

The LM3812/LM3813 current gauges from National Semiconductor are suitable for application as battery charge/discharge gauge, motion control diagnostics, power supply load monitoring and management, and resettable smart fuse.

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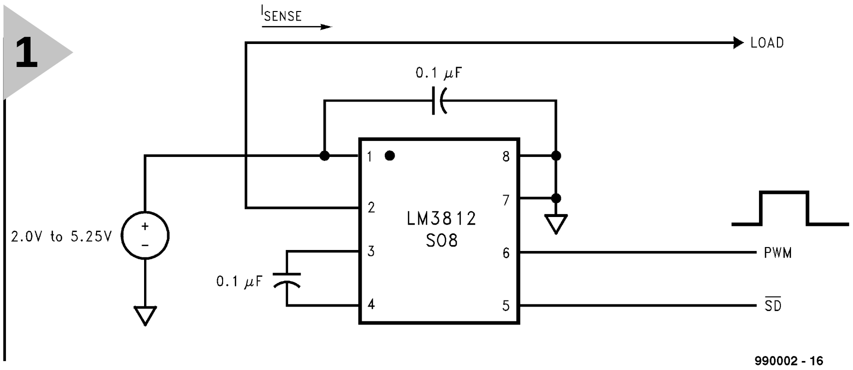

Figure 1. Typical application circuit of an LM3812 (high sense). That of an LM3813 (low sense) is equally straightforward.

INTRODUCTION

The LM3812/LM3813 current gauges provide easy-to-use precision current measurement with virtually zero insertion loss (typically 0.004 Ω; temperature coefficient 2600 ppm °C^{-1}).

A Delta Sigma analogue-to-digital converter is incorporated to precisely measure the current and to provide a current averaging function. Current is

Main parameters

- *Ultra low insertion loss (typically 0.004 Ω)*
- *2–2.5 V supply range*
- *±2% accuracy at room temperature (includes accuracy of the internal sense element) (LM3812-1.0, LM3813-1.0)*
- *Low quiescent current in shutdown mode (typically 2.5 µA)*
- *50 ms sampling interval*
- *No external sense element required*
- *PWM output indicates the current magnitude and direction*
- *PWM output can be interfaced with microprocessors*
- *Precision delta-sigma current-sense technique*
- *Low temperature sensitivity*
- *Internal filtering rejects false trips*
- *Internal power-on reset (POR)*

A National Semiconductor Application

averaged over 50 ms time periods to provide immunity to current spikes.

The devices have a pulse-width modulated (PWM) output which indicates the current magnitude and direction. The accuracy, including the accuracy of the internal sense element, is better than ±2% at room temperature.

The shutdown pin may be used to inhibit false triggering during start-up or to enter a low quiescent current mode.

The LM3812 is used for high-side sensing, and the LM3813 for low-side sensing. The diagram of the LM3812 in **Figure 1** shows that the only external components needed are two capacitors. The application diagram of the LM3813 is equally straightforward.

Both ICs operate from a supply voltage of 2–5.25 V. They are factory-set in two different current options. The sense range is –1 A to +1 A or –7 A to +7 A. The sampling interval is 50 ms. If faster sampling is desired, reference should be made to the LM3814 and LM3815.

The devices are available in eight different versions in an SO8 package. In the type coding LM381aXc-d, M indicates that the part is available in surface mount package; a indicates high-side (=2) or low-side (=3); X indicates that the part is available in multiples of 2500 on tape or reel; c indicates the sampling time (c=P=50 ms; c=F= 6 ms), and d indicates the sense range (d=1.0 for ±1 A; d=7.0 for ±7 A).

OPERATION

The current is sampled by a delta-sigma modulator as shown in **Figure 2**. The pulse density output of the modulator is digitally filtered. The digital output is then compared to the output of a digital ramp generator, which produces a PWM output.

The duty cycle of the PWM is proportional to the level of current flowing. A duty cycle of 50% indicates zero current. If the current is flowing into a positive direction, the duty cycle >50%; if it is flowing into a negative direction, the duty cycle <50%.

A duty cycle of 95.5% (4.5%) indicates the current is at I_{max} ($-I_{max}$). The IC can sense current from $-I_{max}$ to $+I_{max}$. Options for I_{max} are 1 A or 10 A. A typical timing diagram for a mostly positive current is given in **Figure 3**. The sense current is given by

$$I_{sense} = 2.2(D-0.5)(I_{max})$$

where D is the duty cycle of the PWM signal and I_{max} is the full-scale current (1 A or 10 A). Similarly, the duty cycle is given by

$$D = (I_{sense}/2.2I_{max}) + 0.5.$$

2

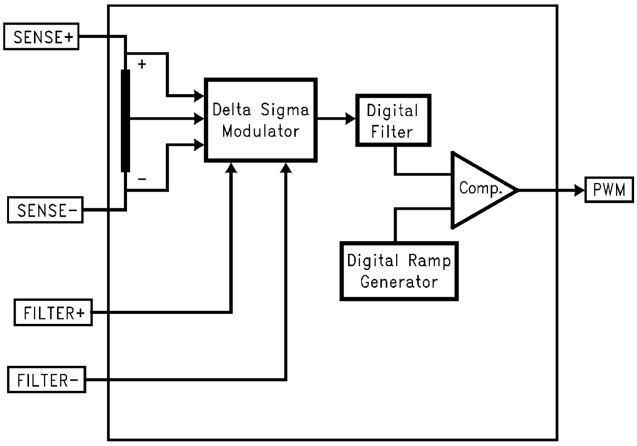

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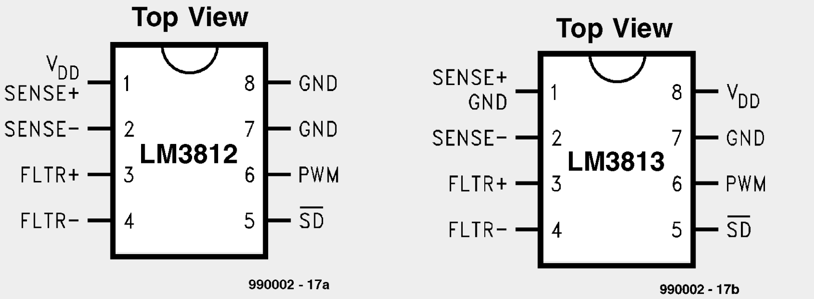
Figure 2. Functional block diagram of the LM3812/LM3813.



Pin description

1	*SENSE+*	*High side of internal current sense, also supply voltage (ground in LM3813)*
2	*SENSE–*	*Low side of internal current sense*
3	*FLTR+*	*Filter input provides anti-aliasing for delta-sigma modulator*
4	*FLTR–*	*Filter input*
5	*SD*	*Shutdown pin. Connected to V_{DD} through a pull-up resistor for normal operation.* *When low, the IC goes into a low-current mode (typically 3µA)*
6	*PWM*	*PWM output indicates the current magnitude and direction*
7	*GND*	*Ground*
8	*GND*	*Ground, but V_{DD} in LM3813*

Figure 3. Typical timing diagram for mostly positive current. The duty cycle of the PWM signal during any sampling interval indicates the current magnitude (average) and direction during the previous sampling interval.

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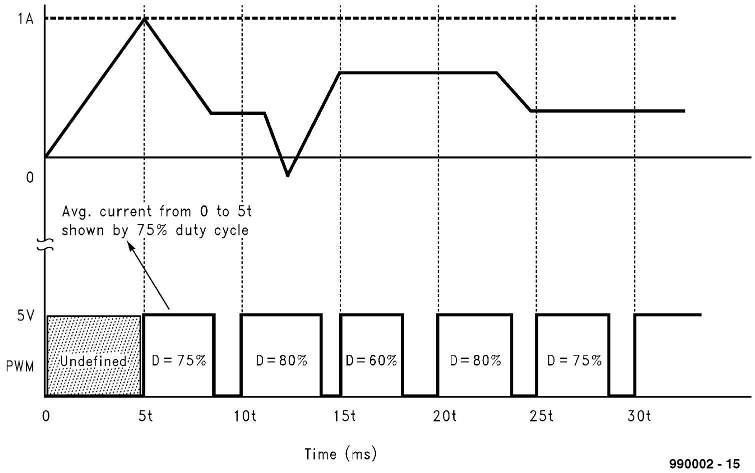

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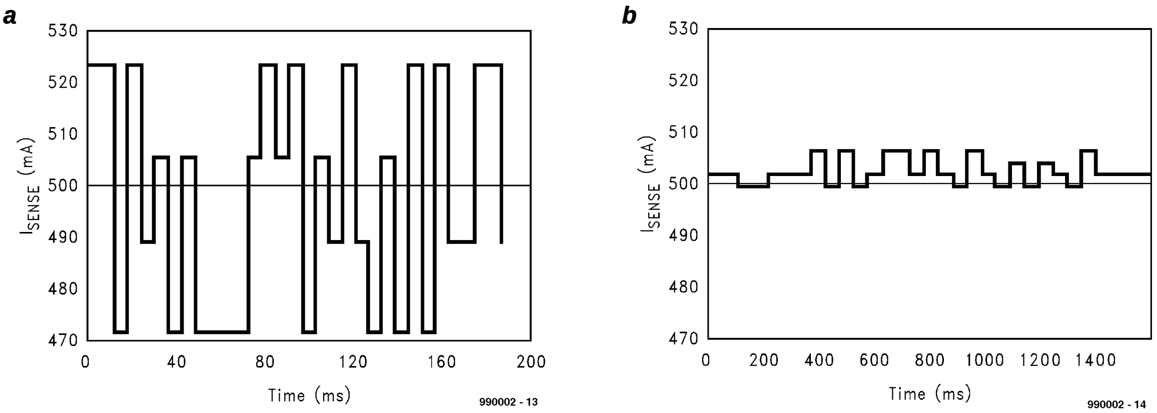

Figure 4. Typical response of an LM3812-1.0/LM3813-1.0 P version (a) and F version (b).

Note that although the LM3812-7.0 and LM3813-7.0 will read 10 A full scale, they are rated for 10 A operation for a duration of no more than 200 ms, and 7 A operation continuously.

OFFSET

The PWM output is quantized to 1024 levels, which means that the duty cycle can change in increments of 1/1024 only.

There is a one-half quantization cycle delay in the output of the PWM circuitry. That is to say that instead of a duty cycle of n/1024, the duty cycle actually is (n+0.5)/1024.

The quantization error can be corrected if a more precise result is desired. To correct for this error, simply subtract 1/2048 from the measured duty cycle.

The extra half cycle delay will show up as a d.c. offset of 0.5 bit if it is not corrected for. This is about 1.1 mA for 1 A ICs, and 11 mA for 7 A devices.

ACCURACY VS NOISE

The graph shown in **Figure 4** illustrates the typical response of ±1 A current gauges. In this graph, the horizontal (x) axis indicates time, and the vertical (y) axis, the measured current (the PWM duty cycle has been converted to current). The graph shown was generated for an actual current of 500 mA.

The difference between successive readings manifests itself as jitter in the PWM output or noise in the current measurement (when the duty cycle of the PWM output is converted into current).

The accuracy of the measurement depends on the noise in the current waveform. The accuracy can be improved by averaging several outputs. Although there is variation in successive readings, a very accurate measurement can be obtained by averaging the readings. For example, on averaging the readings shown in this example, the average current measurement is 502.3 mA. This value is very close to the actual value of 500 mA. Moreover, the accuracy depends on the number of readings that are averaged.

[990002]

Source: Data sheet 'LM3812/LM3813 Precision Current Gauge IC with Ultra Low Loss Sense Element and PWM' (National Semiconductor) (www.natsemi.com/)

Electrical characteristics (V_{DD} = 5.0 V, Supply bypass capacitor is 1 µF and filter capacitor is 0.1 µF)

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Units
I_{ACC}	Average current accuracy	LM381aPM-1.0	0.882/**0,864**	0.9	0.918/**0.936**	A
		LM381aFM-1.0	0.868/**0.850**	0.9	0.932/**0.950**	A
		LM381aPM-7.0	2.400/**2.350**	2.5	2.600/**2.650**	A
		LM381aFM-7.0	2.350/**2.288**	2.5	2.650/**2.712**	A
e_n	Effective output noise	LM381aPM-1.0		2		mA
		LM381aFM-1.0		12		mA
		LM381aPM-7.0		20		mA
		LM381aFM-7.0		120		mA
I_{Q1}	Quiescent current	Normal Mode		100	**160**	µA
		Shutdown Mode		2.5	**10**	µA
D_{RES}	PWM resolution	Precision Mode		0.1		%
		Fast Mode		0.8		%
t_S	Sampling time	Precision Mode	**40**	52	**80**	ms
		Fast Mode	**4**	6	**10**	ms
f_P	Frequency of PWM signal	Precision Mode	**12,5**	20	**25**	Hz
		Fast Mode	**100**	160	**250**	Hz
V_{OH}	Logic high level for PWM	Load current = 1 mA	V_{DD} - 0.2	V_{DD} - 0.05		V
V_{OL}	Logic low level for PWM	2V ≤ V_{DD} ≤ 5.25V		0.04	0.2	V
P_I	Insertion loss	I_{SENSE} = 1 A		0.004		Ω

Notes: Specifications in standard type face are for a junction temperature T_j = 25 ∞C and those in bold type face apply over the full junction temperature range of –40 °C to +125 °C.